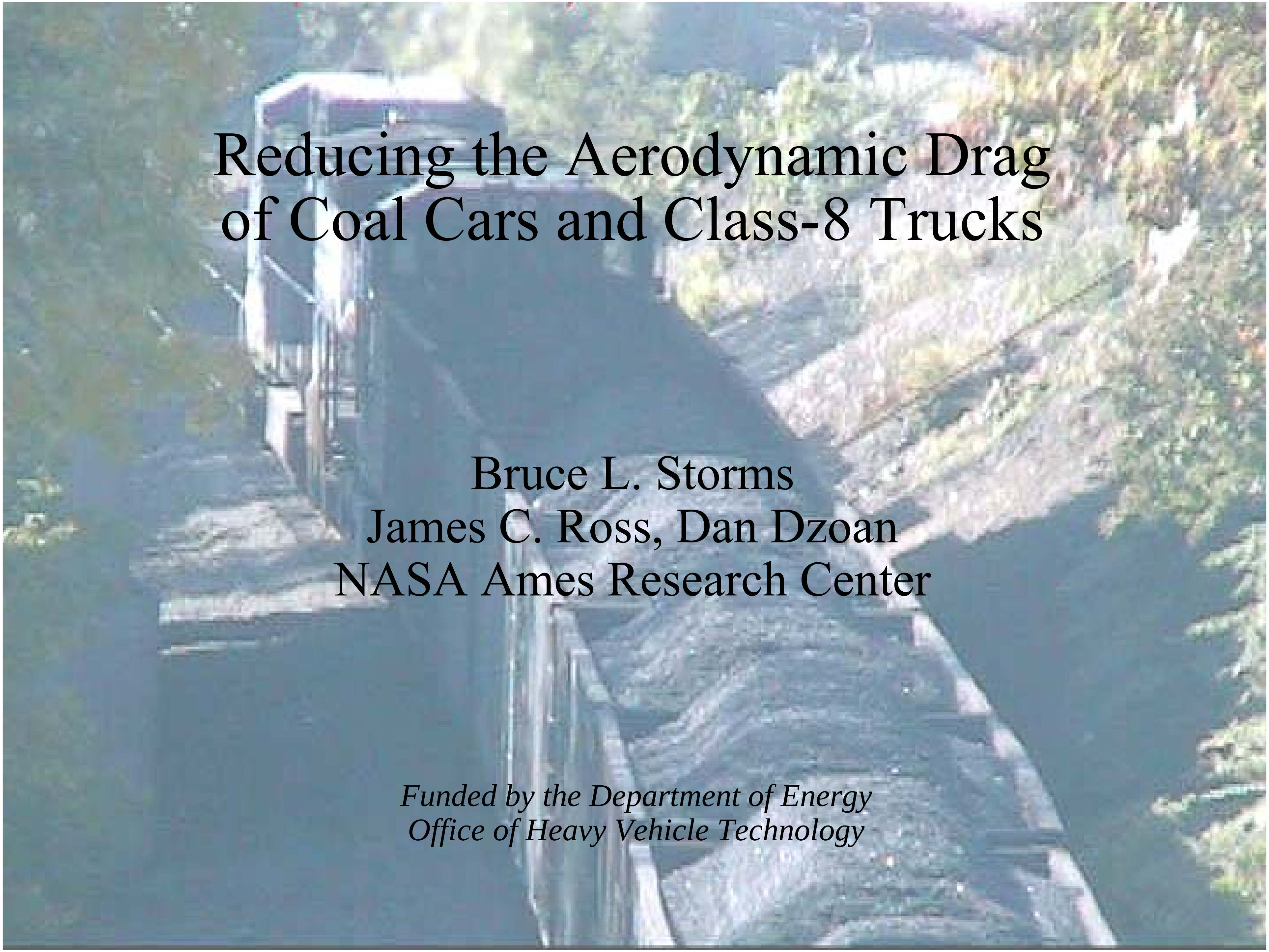


Reducing the Aerodynamic Drag of Coal Cars and Class-8 Trucks

Bruce L. Storms

James C. Ross, Dan Dzoan

NASA Ames Research Center

Funded by the Department of Energy

Office of Heavy Vehicle Technology

Outline

- DOE Program
- Aerodynamic Drag Reduction for Trucks
- Aerodynamic Reduction for Coal Cars
- Results
- Summary

DOE Heavy Vehicle Drag Reduction Program

- Established in 1998
- Consortium of government laboratories and universities
  - Lawrence Livermore National Laboratory
  - Sandia National Laboratory
  - Argonne National Laboratory
  - NASA Ames Research Center
  - University of Southern California
  - Caltech
- Additional funded activities at Auburn University, Georgia Tech Research Institute, and with a consortium of tractor manufacturers

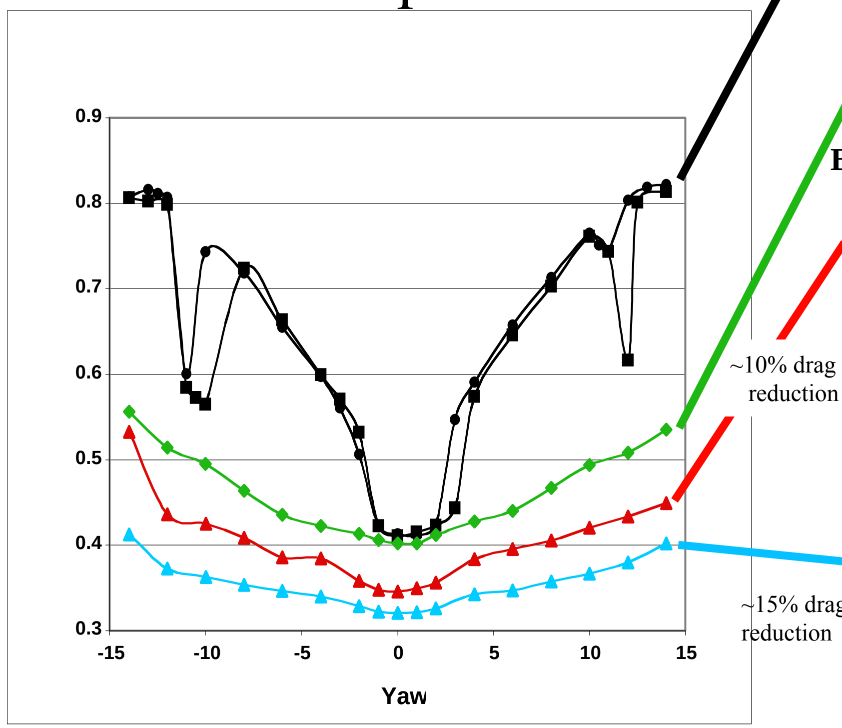
Why Reduce Aerodynamic Drag of Trucks?

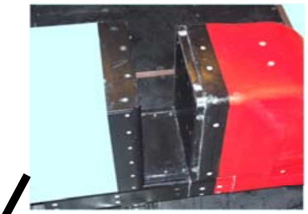
- Class 3-8 trucks account for ~25% of road vehicle fuel consumption in the US
- Aerodynamic drag at highway speeds accounts for 60% of energy expended by typical tractor trailer
- Relatively straightforward devices can reduce aerodynamic drag by 25-50%
- ***Potential savings of up to 1.5 billion gallons of fuel per year***

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

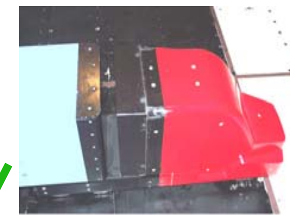
Program Activities

- Development of drag-reduction devices in wind-tunnel and road tests
- Improvements in drag-prediction ability (CFD best practices and code validation)
- Improved understanding of flow physics using computations and experiments

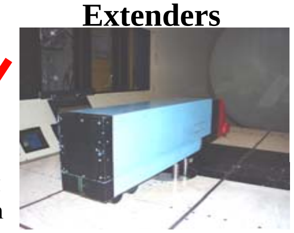




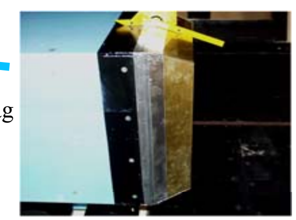
No Gap Treatment



Baseline Side and Roof Extenders



Lowboy Trailer

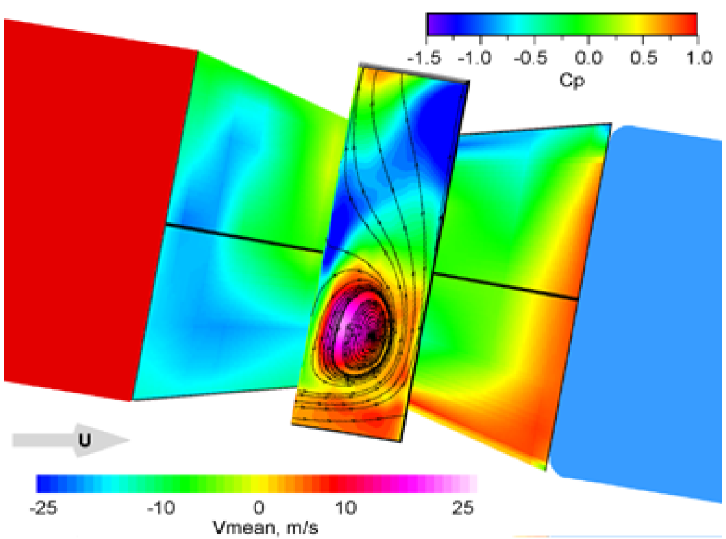


Trailer Base Flaps

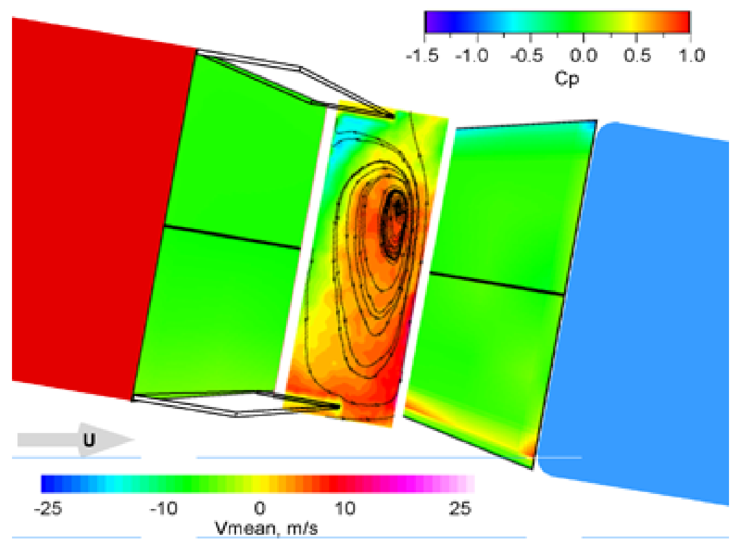
Computed Flow Around Tractor Trailer

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Measured Surface Pressures & Air Velocity in Gap Between Tractor and Trailer



Baseline



Side Extenders

Why Reduce Aerodynamic Drag of Coal Cars?

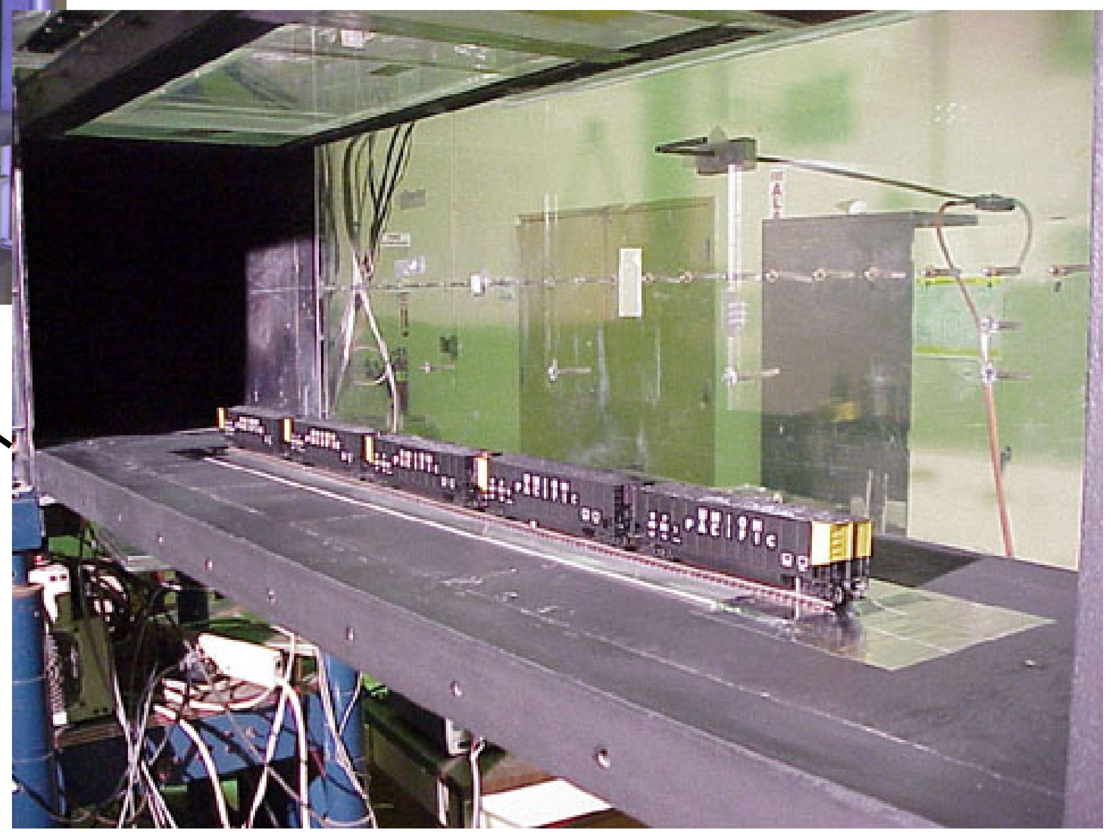
- 2002 U.S. Statistics*
  - Coal provided 50% of electrical power
  - Total = 1 billion tons, 66% carried by rail
  - 44% tonnage, 25% loads, 21% revenue
  - 85% by unit trains (50+ cars)
  - Average coal haul = 696 miles
- Aero Drag Reduction Potential
  - ***Fuel consumption: empty ≈ full***
  - Aero drag ~ 15% of round-trip fuel consumption
  - 25% reduction –> 5% fuel savings (75 million gal)

* The Rail Transportation of Coal, AAR, Vol. 5, 2003

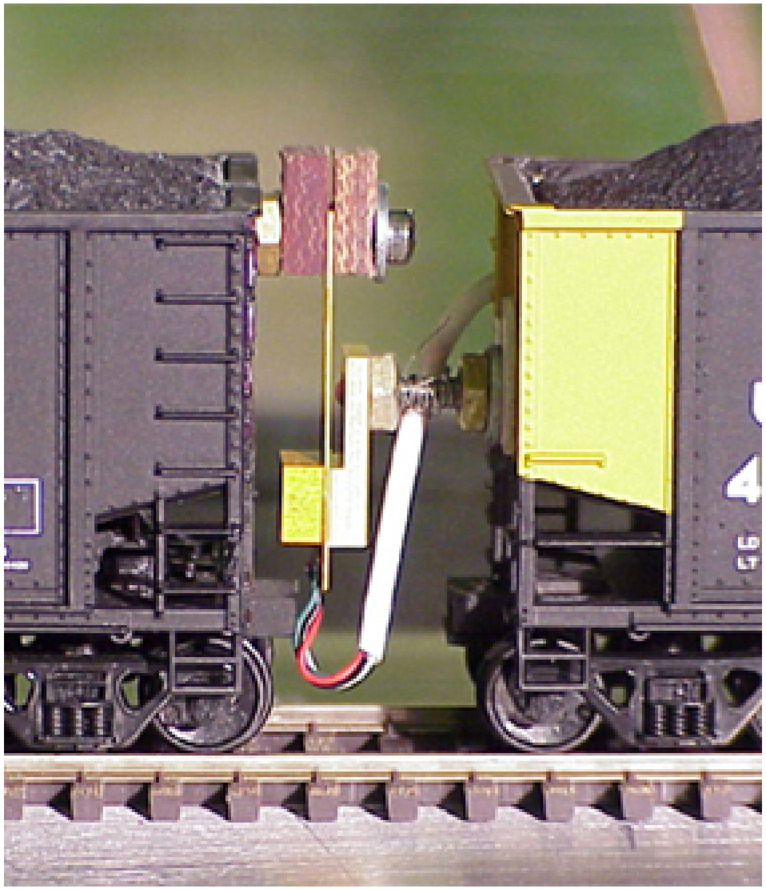
Wind Tunnel Testing

15x15" Wind Tunnel

Model Installation in Test Section



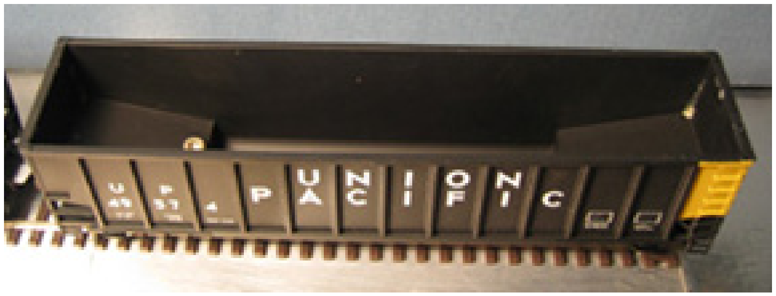
Test Details

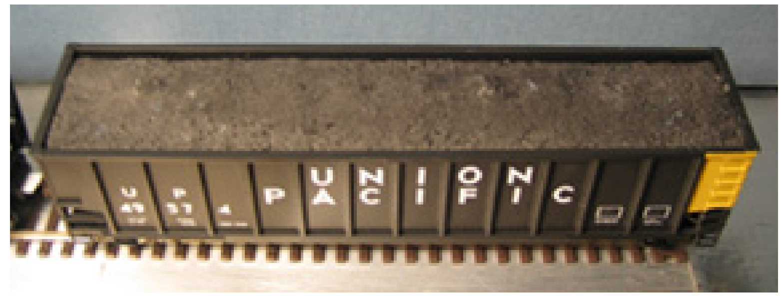


- Drag force measured using 2-lb load cell
- Test Conditions
  - Velocity = 65 m/s (145 mph)
  - Model Reynolds No. = 160,000

  (full-scale Re = 3.9 million at 40 mph)
  - Critical Re = 10,000
- Yaw angles 0° to 10°
- Uncertainty:
  - 1.0 - 1.5% for yaw ≤ 5°
  - 2.5 - 4.9% for yaw > 5°

Empty vs Full Cars

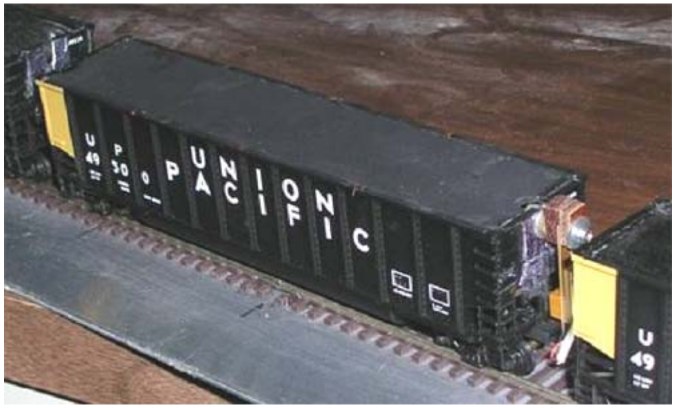




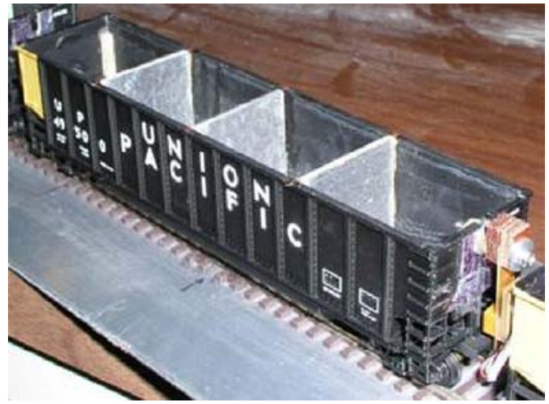
Yaw (ψ, deg)	C_D empty	C_D full	C_R empty	C_R full	%difference (full-empty)
0	0.3334	0.2358	0.0924	0.0653	-29.3
10	0.6015	0.3519	0.1719	0.1006	-41.5

$$C_D = D / q{*}A \text{ where } q = {}^1/_2\, \rho U^2$$
$$C_R = 1.0756\, \rho\, A\, C_D / \cos^2 \psi \text{ , lb/mph}^2$$

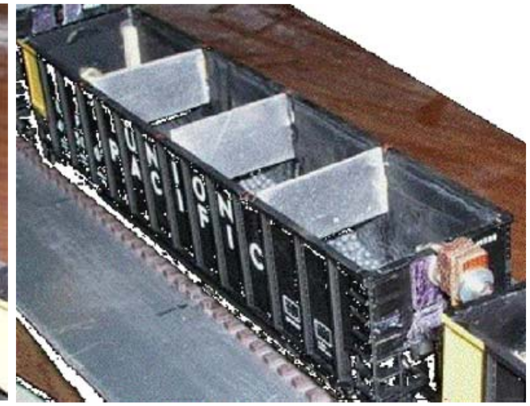
Cover & Divider Configurations



Cargo-bay Cover

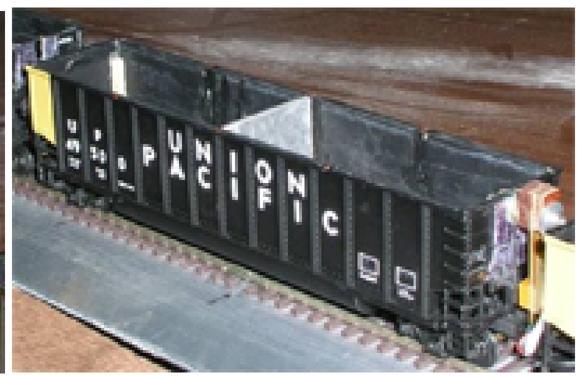


3 Full Dividers



3 Half Dividers

Elevated Dividers

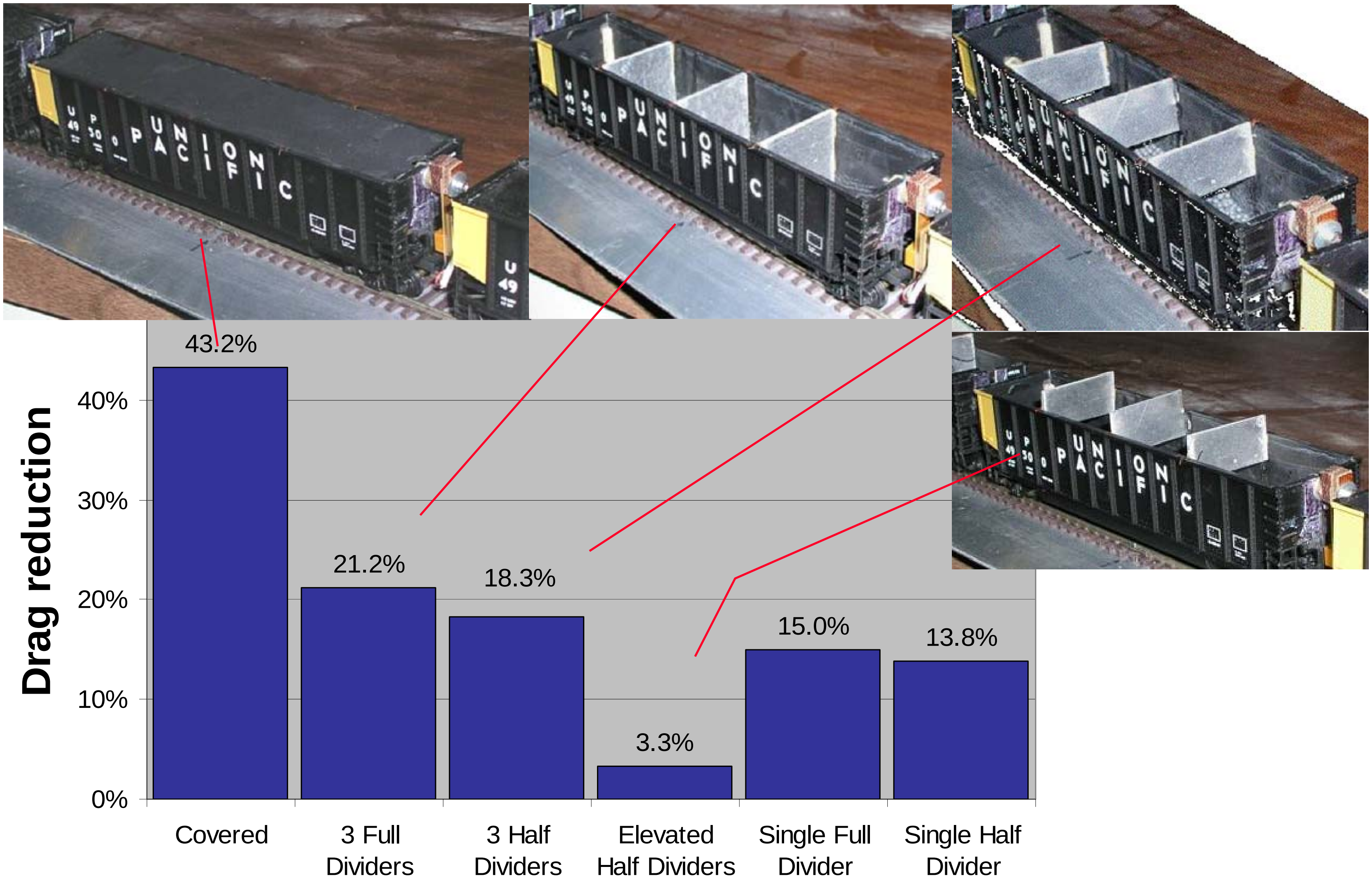


Single Full Divider

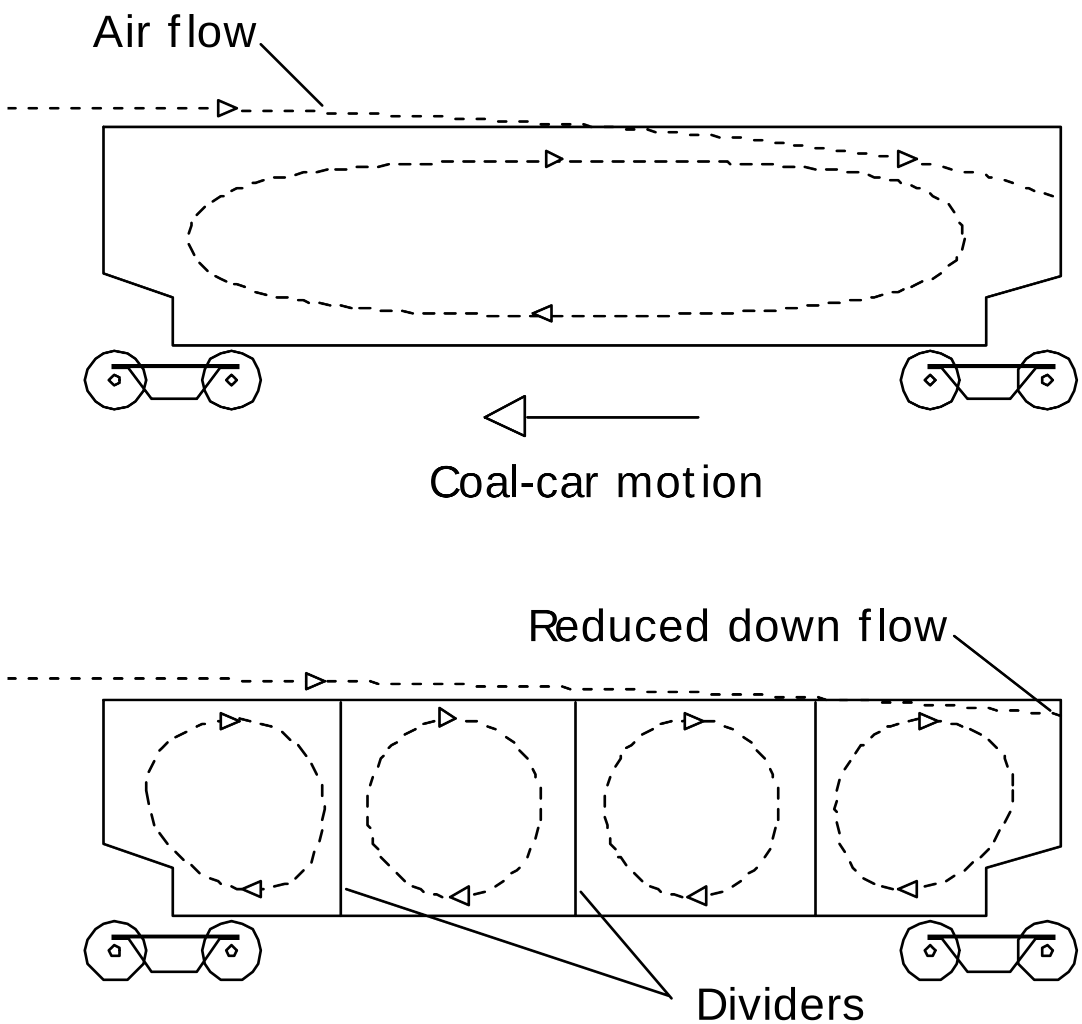
Single Half Divider

Cover & Divider Configurations

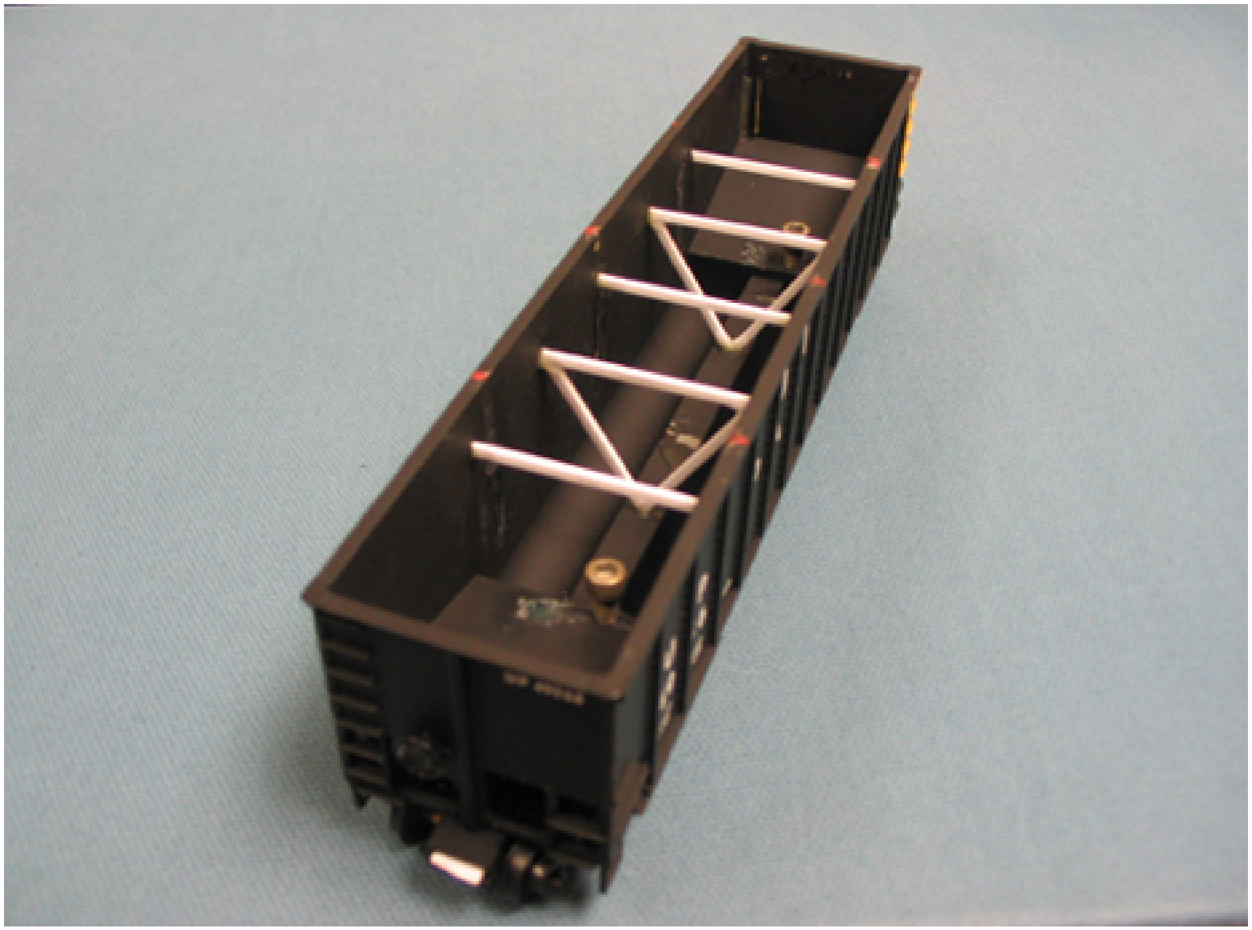
(ψ = 0, no crosswind)



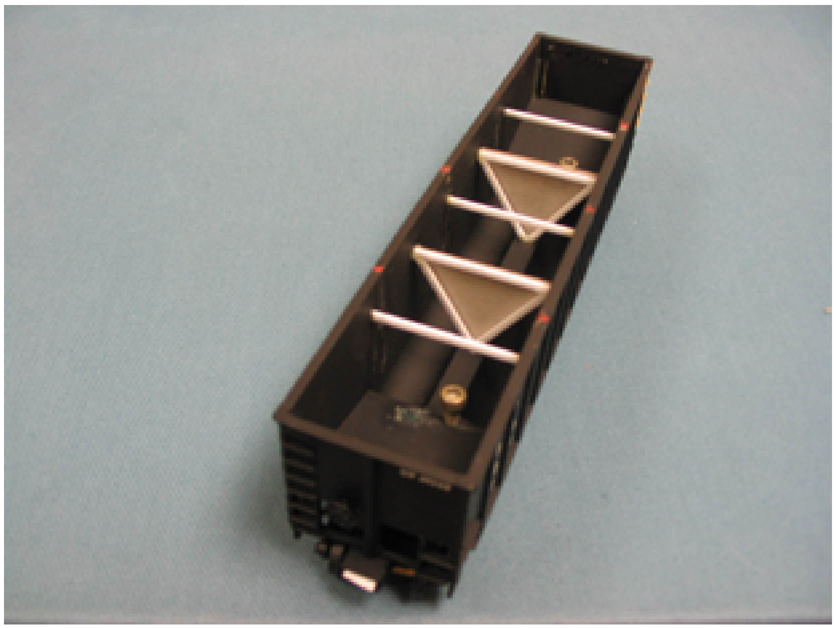
Hypothesized Flow Field



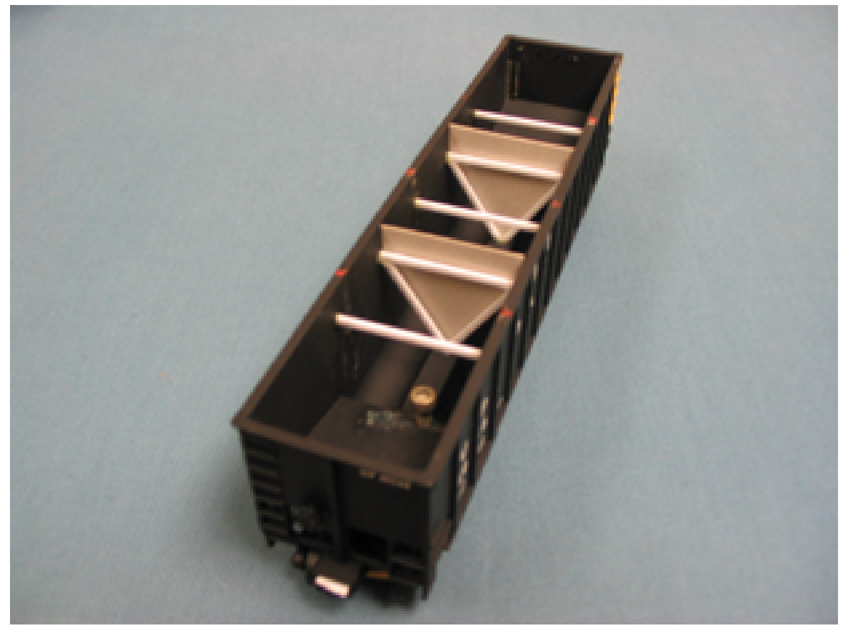
Internal Bracing



Internal Bracing with Dividers

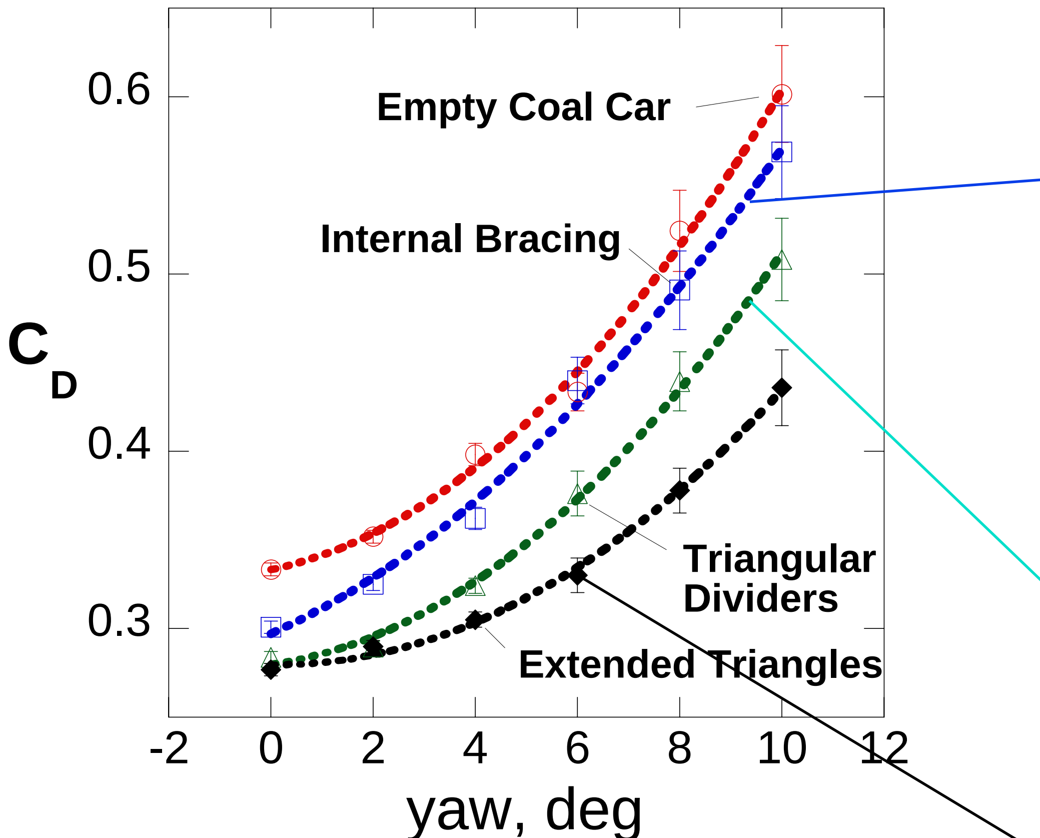


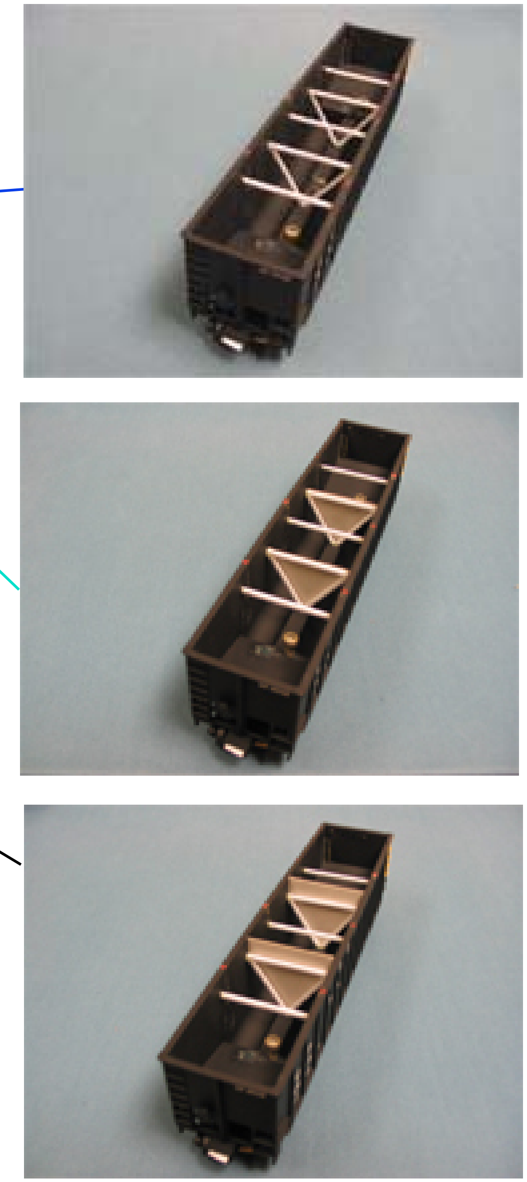
Triangular Dividers



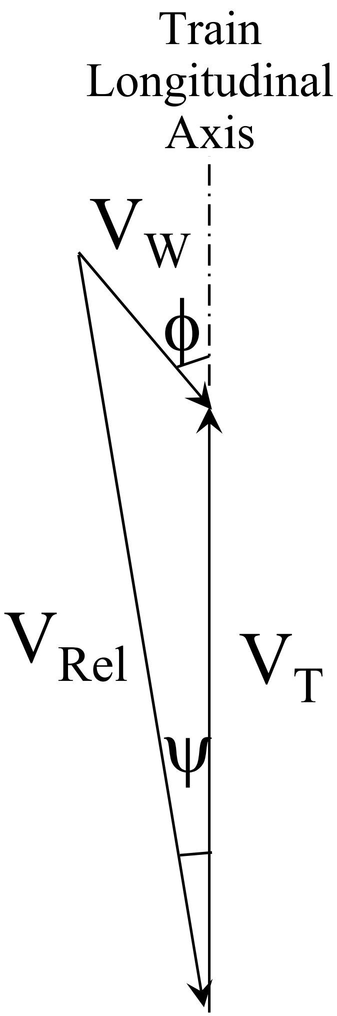
Extended Triangles

Effect of Bracing & Dividers





Wind-Averaged Drag, $\overline{C}_D$



$$\overline{C}_D(V_T) = 1/6 \sum_{j=1}^{6} M(j)\, C_D(j)$$

$$M(j) = 1 + (V_W/V_T)^2 + 2(V_W/V_T)\cos\phi(j)$$

$$\phi(j) = (j \times 30\text{ deg}) - 15\text{ deg}$$

$$C_D(j) = C_D \text{ at } \psi(j)$$

$$\psi(j) = \tan^{-1}\left[\frac{(V_W/V_T)\sin\phi_j}{1 + (V_W/V_T)\cos\phi_j}\right]$$

Mean wind speed, V_w = 7 mph

From SAE Recommended Practice, SAE J1252, 1981.

Wind-Averaged Drag & Resistance

Configuration	$\overline{C}_D$ wind-avg.	%diff	ΔR, lbs 100 cars, 40 mph
Internal Bracing	0.464	0.0	0
Empty	0.490	+5.2	+ 1133
Triangular Dividers	0.412	-15.8	-2310
Extended Triangles	0.366	-25.2	-4340

Summary

- Zero-Crosswind Drag Reduction (relative to empty cars)
  - Full Coal Load: 29%; Covered Car: 43%
  - Three full-height dividers: 21%
  - Two triangular dividers: 15% & 17%(extended)
- Wind-averaged Drag Reduction
  - Two triangular dividers: 16% & 25% (extended)

>> 25% reduction –> 5% fuel savings (75 million gal/yr)

>> Can be retrofit by attaching to internal bracing

Future Work

- Larger scale testing
- Optimization
  - – Dividers size, shape, location, porosity
  - – Operational conditions / constraints
- Full-scale validation tests at Transportation Technology Center in Pueblo, CO